Muscle tissue- part 2

When action potential reaches the interior of the muscle cell through T tubules, calcium will be released and that will lead to muscle cell contraction.

When stimulation occurs, nerve endings release certain neurotransmitters and they bind to certain receptors on the sarcolemma leading to depolarization and that depolarization will propagate and reach each myofibril within the cell and once it reaches the triad area, it triggers the release of calcium ions from the sarcoplasmic reticulum.

Calcium (from the sarcoplasmic reticulum) will bind to troponin causing conformational changes that stimulate tropomyosin to leave the complex exposing the binding sites on actin and now the myosin head will interact with its binding site on actin.
We call the binding between actin and myosin: cross bridge.

In order for the myosin head to detach from actin, it needs ATP (the cross bridge will be removed).

After death we have something called rigor mortis (rigor=stiffness, mortis=death) and that's because after death there is no oxygen and no ATP (mitochondrial activity stops after death). Myosin will not be able to detach from actin and the muscles are unable to relax. Rigor mortis means postmortem rigidity, and is one of the recognizable signs of death. It occurs in all muscles, all muscles become rigid and the body is hard to move. Rigor mortis usually starts after four hours and peaks at 12 hours, first in the face and generally smaller muscles. Decomposition of the myofilaments occurs 48 to 60 hours after the peak of rigor mortis by endogenous enzymes and bacteria

The junction between the motor neuron and the skeletal muscle cell is called the neuromuscular junction or the neuromuscular synapse or motor end plate

Motor unit:

The motor unit is defined as the muscle cells that are supplied by a single neuron/axon; its size is variable according to the muscle action. EX: quadriceps muscle is a large muscle and its contraction is gross, a single axon supplies hundreds of muscle fibers. While the small muscles of the hand have small motor unit; up to ten muscle cells are supplied by a single axon (fine and precise movement), another example is the muscles of the eye: one axon supplies one or two muscle fibers in order to produce a fine, delicate movement. The finer the movement, the fewer muscle fibers per motor unit (smaller motor unit).

Muscle spindle

- Acts as proprioceptors (proprioception: muscle sense)
- Acts as stretch detectors
- Provides the central nervous system (CNS) with data from musculoskeletal system
- A muscle spindle is encapsulated by a modified perimysium
- Contains few thin modified muscle fibers filled with nuclei
- Called also intrafusal muscle fibers
- Sensory axons wrap around individual muscle fibers
- Detects any change in the length and tension of the muscle caused by body movement, and sends this information to CNS to detect the position of body parts. With this information, the CNS computes the position and movement of our extremities in space, this is necessary for maintaining posture and for a stable gait
- Most of this proprioceptive information is processed at a subconscious level

Types of skeletal Muscle fibers:

We have 3 different types of skeletal muscle fibers in our body:

1. Slow fibers (Red Muscles)
2. Fast fibers (White Muscles)
3. Intermediate fibers.

The main difference between types is how they produce ATP. The color of the muscle is different (Grossly not histologically)

Slow Fibers (Red Muscles):

- ✓ They produce their ATPs by Oxidative phosphorylation in Mitochondria, which produces high amounts of ATP in a long time (slow) (Aerobic reactions inside the mitochondria = Oxygen is used)
- ✓ The fuel for the production of ATP is Fatty acids (mainly), fatty acids are produced by metabolism of fats, so in order to burn fat in your body, you need to work aerobically

(Aerobic exercises are called so because people are activating their red muscles to burn fats, so they are usually preceded with warm up exercises, to supply the muscles with adequate amount of oxygen)
(Thin people usually have higher amount of red muscle fibers than white muscle fibers).

- ✓ They look red because:

a. They have high amount of mitochondria
b. They are highly vascularized, because they need high amounts of O2 to produce contraction
c. They contain high amounts of Myoglobin (Hemoglobin like protein, has heme (iron), and is an oxygen binding protein)

All these features make the fresh red muscle tissue dark or red in color.

- ✓ The ATPase activity of their myosin heads is low, so the contraction is slow
- ✓ This slow contraction is prolonged (for a long time but slow). Remember here that we have high amount of ATP to maintain contractions for long time
- ✓ They don't get Fatigue easily.

Examples: Spinal muscles, muscles of the back, hip flexors (postural muscles are mainly red fibers)

Fast Fibers (White Muscles)

- ✓ They are white in color, because they don't have high amounts of myoglobin and mitochondria.
- ✓ They don't need Oxygen to produce ATP (Anaerobic reactions in the cytoplasm instead of mitochondria).
- ✓ Glycolysis: production of ATP without the need of oxygen, it occurs in the cytoplasm directly and quickly.
- ✓ They are called Fast fibers because: They produce ATP quickly within the cytoplasm by glycolysis, they produce fast contractions
- ✓ The ATPase activity of their myosin heads is high
- ✓ They are larger than red fibers.
- ✓ They produce fast and strong contractions but for short time.
- ✓ Activated in weight lifting activities (resistance exercises), for example if you are carrying a heavy object, you give maximum force but this contraction will not last for a long time

For Example: people who sprint (run at maximum speed for short distance) produce very strong contractions for a short period of time (have high amount of white fibers), while Marathon runners have higher amount of red fibers, they run long distance for a long period of time without getting fatigue (their speed is moderate).

- ✓ Why do they look white?

A. They have few mitochondria, less capillaries

B. They store high amount of glycogen

- ✓ They get fatigue easily because one of the byproducts of Glycolysis is Lactic acid (it causes burning sensation but it will be absorbed soon).
- ✓ The fuel for these muscles is mainly: Glucose.

Third: Intermediate Fibers:

1. They have characteristics between both the white and the red
2. They are more resistant to fatigue than the white fibers but less than the red.
3. They are faster than red muscle fibers.

MOTOR UNIT: number of muscle cells supplied by a single Axon

- Each motor unit is composed of certain type of muscle fibers, red or white. So *All muscle fibers of a motor unit are of the same type*

Skeletal muscles contract when they are stimulated, if you cut the nerve supply, paralysis will occur

Muscle atrophy: loss of tone and mass from lack of stimulation. Muscle becomes smaller and weaker. This is could be a result of not using the muscle (disuse atrophy)

Muscle Hypertrophy:
Hypertrophy: is an increase in the size of the muscle.
By increasing the synthesis of their proteins (synthesis of more actin and myosin), so the myofibril itself gets thicker and so on, and the size of the muscle will increase.

Hyperplasia:
Hyperplasia: increase in the number of the cells
- Skeletal muscle cell can undergo hypertrophy (highly muscular people), and it can rarely undergo hyperplasia because the amount of the satellite cells is very minimal.

Note that satellite cells are undifferentiated stem cells (myoblasts) and they remain in the skeletal muscle tissue after differentiation
Satellite cells proliferate and produce new muscle fibers following muscle injury.

Remember, skeletal muscle cells cannot undergo mitosis (they are highly differentiated), however, the skeletal muscle tissue can still display limited regeneration. The source of regenerating cells is the satellite cells. After injury, satellite cells proliferate, differentiate and fuse to form new skeletal muscle fibers. So skeletal muscle cells have limited capacity for regeneration (because we have few satellite cells in skeletal muscle tissue).
Generally, skeletal muscle tissue is replaced by proliferating fibroblasts and growth of connective tissue, forming only connective tissue scars.

ALL OR NONE principle: each muscle fiber either contracts completely or not at all, why? due to the presence of T-tubules (invaginations from the sarcolemma and they reach each myofibril within the muscle cell) so when the action potential reaches the muscle cell, all the myofibrils within the muscle cell will contract/shorten leading to the all or none principle. This applies also to the motor unit, either there is contraction in all the muscle cells that belong to one motor unit or there is no contraction at all